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**DIVISION OF AGRICULTURAL SCIENCES
UNIVERSITY OF CALIFORNIA**

Some Aspects of Labor Efficiency In Canning Asparagus Spears

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and

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**CALIFORNIA AGRICULTURAL EXPERIMENT STATION
GIANNINI FOUNDATION OF AGRICULTURAL ECONOMICS**
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FOREWORD

This is the first in a series of research reports by the University of California on the competitive position of the western canned fruit and vegetable industry conducted under a regional research project by the Agricultural Experiment Stations of California, Oregon, and Washington, in cooperation with the Economic Research Service, U. S. Department of Agriculture.

The major objective of this study is the analysis of existing manual canning labor utilization in asparagus canning plants. Labor utilization under conventional canning methods is compared with recently developed mechanical presizing equipment.

Economic and engineering research procedures were used in a synthesis of labor requirements for a single product output of green and white asparagus spears.

This report should supply useful information to management of individual firms in efforts to improve operating efficiency and in determining possible short-run adjustments. These results are also being applied to continuing studies of interregional competition in the canning industry.

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Special credit is due L. L. Sammet and B. C. French of the Giannini Foundation for their encouragement and help in all phases of the study. The authors are indebted to J. N. Boles and I. J. Hoch for their aid in formulating the statistical procedures used in this report. Thanks are also due L. C. Martin, C. D. Jackson, and J. O. Gerald of the Marketing Economics Division, Economic Research Service, U. S. Department of Agriculture; A. H. Harrington of the Department of Agricultural Economics, Washington State University; and members of the Regional Technical Committee for helpful comments. Mrs. C. Cartwright of the Giannini Foundation gave valuable assistance in the statistical computations.

Essential contributions to the study were made by the California canning industry. While it is difficult to single out individuals in this connection, the authors wish to extend particular thanks to the following individuals and organizations: Vincent and Bert Davi, Western California Canners, Ltd.; S. Ross, Martinez Food Canners, Ltd.; B. Allewelt and L. L. Lehtin, Tri-Valley Packing Association; D. G. Hollenbeck and B. Casado, California Canners and Growers, Inc.; P. Rea, U. S. Products Corp., Ltd.; L. Tucker, Sterling Industries; J. E. Wahlberg and D. Childs, Libby, McNeill & Libby; A. Flodin, Flodin, Inc.; and A. Westberg, The Mave Company.

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Summary

The major objective of this study is the analysis of existing manual canning labor in asparagus canning plants. Labor utilization under conventional canning methods is compared with recently developed mechanical presizing equipment. Statistical, economic, and industrial engineering research techniques are used to identify and analyze the principal variables affecting labor productivity in manual canning operations.

The results show that the physical characteristics of the asparagus spears such as color and diameter, the size of the container being packed, and the quantity or line-load of spears available to successive work stations along the supply conveyor are important factors affecting the rate of canner output. Interactions among these variables are shown to have a significant effect on canner productivity. Several general characteristics of canner productivity are noted.

First, canner output rates at any given position along the canning line are shown to increase with increases in line-load and average spear size distribution. For example, the time to can a No. 300 can-size equivalent for a worker stationed at position 10 is about 0.5 minute with an average line-load of 130 cans per worker hour. This time decreases to about 0.4 minute per can with a line-load of 160 and amounts to only 0.3 minute for a line load of 190.

Second, output rates per canner for any given size distribution and line-load decrease as the position of the worker from the beginning of the line is increased. With an average line-load of 160 cans per worker hour, for example, the weighted average time, by spear size, to can a No. 300 can-size equivalent is about 0.2 minute for workers stationed at position 1. For workers at position 10, the weighted average time to can increases to about 0.4 minute per can and amounts to nearly 0.8 minute per can for workers located at position 18.

Third, output rates of successive cannery workers along the line are affected by interrelationships among position, size, and line-load variables. The effects of these interrelations are so pronounced that it is possible to segment canner's positions along any given line into "productivity zones." The boundaries of each zone identify the line positions where changes in proportions of sizes available, along with an increased number of decisions the canner must make, result in relatively large decreases in canner productivity.

Canning labor costs corresponding to selected values of the above parameters are also presented. Changes in labor costs per can in relation to changes in line-load and position along the canning line are substantial. For example, the cost per can at position 1 varies from 0.0102 cent to 0.0072 cent when average line-load changes from 130 to 190 No. 300 can-size equivalents per hour. At a line-load of 190 cans per hour, labor costs per can range from 0.0072 cent to 0.01894 cent as paired canner position is varied from 1 to 18. The large differential in labor cost per can reflects a large degree of labor underutilization for workers stationed near the lower end of the canning belt. Such underutilization is difficult to remedy, however, because of the many different sizes of asparagus spears that are packed and because of the policy of many plant operators to "save" all available spears rather than to utilize larger proportions as cut spears and tips. To analyze this policy effectively would require detailed information on the prices of canned asparagus spears relative to prices of canned cut spears and tips. Price data for the two styles of pack were not available in the detail and quantities required for such an analysis.

The use of presizing equipment reduces the task of selecting the proper size or size range to be canned by each canner. Work-sampling studies on the proportion of time spent on each element of the canning operation revealed an approximate 7 percent increase in actual canning time, as a percent of total

time, for white asparagus and a 10 percent increase for green asparagus over the conventional canning method.

The difference in labor requirements between the conventional and presized canning methods will be proportionately constant since canner output rates under the two methods are linearly related to line-load. At a line-load rate of 170 cans per worker hour, the presized method requires six canners less than the conventional canning method. This differential results in a reduction of labor costs of \$13.46 per hour. For plants with an operating season of 500 hours, labor cost savings per season could amount to \$6,730. Other estimates could be made involving other line-load rates and lengths of season.

SOME ASPECTS OF LABOR EFFICIENCY IN CANNING ASPARAGUS SPEARS

by

Robert H. Dawson^{1/} and Robert H. Reed^{2/}

Introduction

For over 15 years the Pacific Coast states, particularly California, have been the largest producers of the national supply of canned asparagus. This has represented over 63 percent of the total annual United States output of canned asparagus and amounted to \$17 million in grower revenues.

Large amounts of labor and material are required in preparing and processing canned asparagus, and prices of these inputs have risen steadily. The development of efficient production and processing methods is of major concern to growers and canners in their efforts to offset rising costs of labor and material and increasing competition from other geographical areas. An important part of this broad problem is analysis of operations and costs of asparagus canning plants, with emphasis on maintaining and improving plant efficiency in the West.

The specific objective of this initial study is the analysis of existing manual canning labor utilization as compared to labor efficiency with improved crew organization and recently developed machine aids, such as mechanical presizing equipment. A later report will include results of an economic-engineering analysis with respect to labor and equipment requirements as well as costs among different methods of receiving, preparation, processing, and warehousing.

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Framework of Analysis

General Considerations

The assignment of canning asparagus consists of manually selecting spears of specified grade and size and placing them, butt down, in cans. This task must be carefully done in order to meet established standards for grade and size, for these attributes have an important impact upon prices. Other in-plant operations, such as dumping, lidding, retorting, etc., have been omitted from this analysis. Canning labor is a major component of total plant labor and accounts for roughly 40 percent of all in-plant labor costs.

The main elements of the canner's work operation include securing an empty can from a can supply point, selecting spears of appropriate size and quality, placing the spears in the can, and setting the full can aside on a conveyor leading to the seamer. Asparagus not packed as spears passes over the end of the canning line and is conveyed to an automatic dicer or chopper for inclusion in the "cut spears and tips" pack.

A relatively new modification to manual canning operations allows pre-selected ranges of sized asparagus spears to reach designated canning belts. With this method, the incoming spears are mechanically sized in relation to their base diameter prior to their discharge onto the canning belt. Controlled experiments with this equipment indicate about 94 percent sizing efficiency with a variance of 0.4 percent.^{1/} Observations in plants where this equipment is in use indicate a sizing efficiency approaching 90 percent may be expected provided the machine is not overloaded.

^{1/} For more detailed information, refer to Flodin, Inc., Sunnyside, Washington, and The Mave Company, Newberg, Oregon.

Output Characteristics and Specifications for Analysis

Among the important factors that affect the rate of individual canner output are the physical characteristics of the asparagus spears such as color and diameter, the size of the container being packed, and the quantity or line-load of spears available to successive work stations along the supply conveyor. A discussion of these factors, together with certain specifications and assumptions of the analysis, is given below.

Color.--Spears for canning may be entirely green, green tipped and white, or entirely white. In this study, the green tipped and white classification is included in the "white" category.

Can Size.--Among the plants observed, asparagus spears were packed in the following can sizes: 8 ounce (buffet), No. 1 (picnic), No. 300, No. 303, No. 2, No. 2½, and No. 5. To provide a standard basis of comparison, all can sizes in this study were converted to a No. 300 can-size equivalent. Conversion factors used were developed from published standards.^{1/} Minor adjustments were made to reflect differences in the fixed labor elements involved in the manual canning job.

Spear Size.--Asparagus spears for canning are classified into six size categories according to their base diameter. These categories are: small, 6/16 inch; medium, 6/16 to 8/16 inch; large, 8/16 to 10/16 inch; mammoth, 10/16 to 13/16 inch; colossal, 13/16 to 16/16 inch; and giant, 16/16 inch and over.^{2/} Asparagus spears are also packed as a blend consisting of two or more of the above sizes.

^{1/} National Canners Association and Agricultural Marketing Service, U. S. Department of Agriculture.

^{2/} For more details as to quality grades, see U. S. Agricultural Marketing Service, U. S. Standards for Grades of Canned Asparagus, fifth issue, effective March 12, 1957.

Table 1 gives the number of white and green asparagus spears typically packed in No. 300 can-size equivalents for the specific size and size blend categories considered in this study. To facilitate the use of spear size as a variable in the analysis, a size index was constructed with the mammoth/large size blend (= 100) as the base of reference. The size index so constructed is shown also in the table. Figure 1 shows the modal distribution of workers performing the canning operation by spear size for both green and white asparagus.

TABLE 1
Number of Spears Per No. 300 Can-Size Equivalent
by Spear Size Classification and Size Index
California, 1964

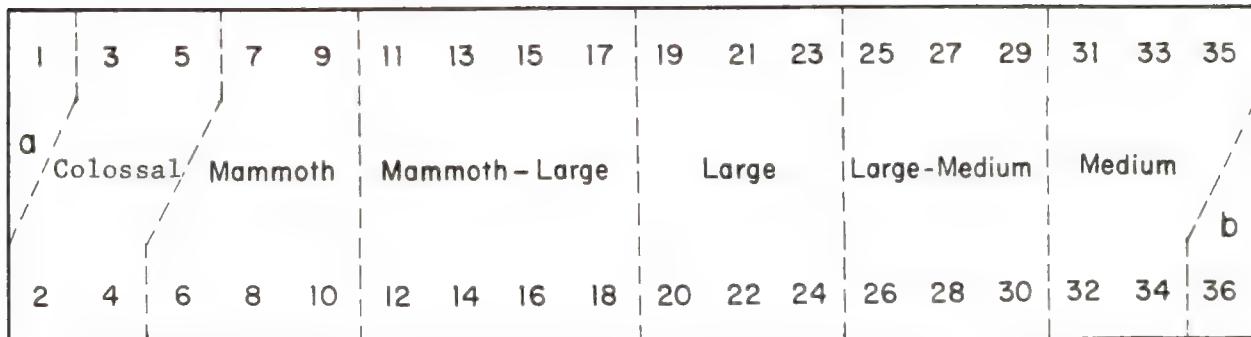
Spear size classification	Number of spears		Size index ^{a/}
	Minimum	Maximum	
Giant	7	9	52
Colossal	9	11	65
Colossal/mammoth	9	15	77
Mammoth	12	16	90
Mammoth/large	13	18	100
Large	17	22	126
Mammoth/large/medium	15	28	145
Large/medium	18	30	155
Medium	23	36	190
Medium/small	31	45	245
Small	42	<u>b/</u>	271

a/ Based on the average of minimum and maximum number of spears with mammoth/large = 100.

b/ Not specified.

Line-Load.--Line-load is defined as the quantity, measured in No. 300 can size equivalents, of canning quality asparagus spears available to workers stationed along any given canning belt. Ideally, this variable should represent all asparagus spears entering the canning area, including quality spears as well as spears with quality aspects unsuitable for canning. Unfortunately, such data

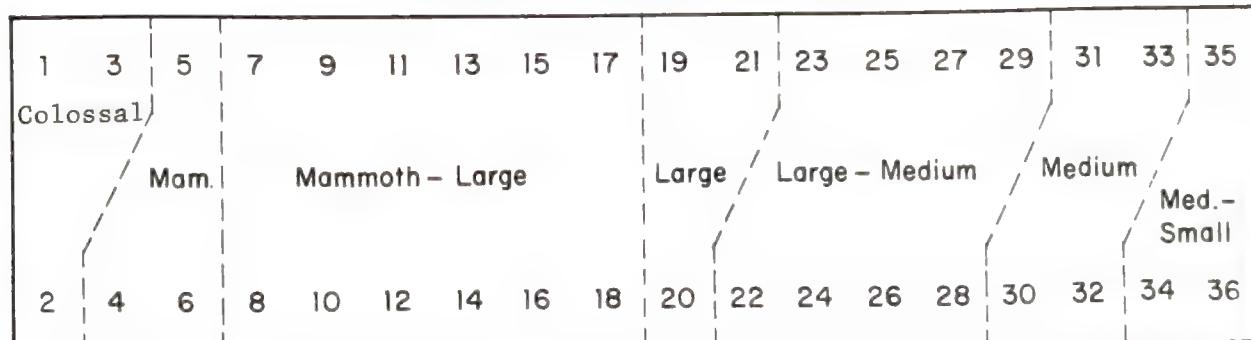
WHITE ASPARAGUS CANNING LINE



a. Giant

b. Medium - Small

GREEN ASPARAGUS CANNING LINE



LEGEND

Each number represents one canner.

Dash lines define selection zones by spear size.

Figure 1. Modal Distribution of Canners by Spear Size for Green and White Asparagus, California, 1964.

were not available in the amount and detail required. However, the quantity of canning quality spears has a proportionate effect on the output of cannerys located all along the canning belt.

Canner Position.--The term position means the individual's location from the beginning of the line. Thus, position 1 is the first canner, position 2 is the second, and so on. Where workers are stationed on both sides of the canning belt, the term position refers also to the location of pairs of cannerys measured from the beginning of the line.

Source of Data

Data on canning labor utilization were obtained from direct work measurement studies of actual operations and from plant operating data in eight California asparagus cannerys. Among the plants studied, line-loads ranged from approximately 2,000 to 9,000 in No. 300 can-size equivalents per belt hour. Despite this broad range in line-loads, the number of cannerys employed per canning line was relatively constant. The typical range observed was 38-42 cannerys per line. This narrow range in crew size among plants, together with the tendency of individual plants to maintain crews of a constant size, prohibited analysis of crew size as a variable.

Time studies were conducted to determine elapsed unit times for each worker. Ratio-delay studies of productive and unproductive times for the main job elements were made to provide meaningful comparisons for minor procedural modifications among different plants.^{1/}

^{1/} For example, see Ralph M. Barnes, Work Sampling (Dubuque, Iowa: William C. Brown Co., 1956), 264p.

See, also, L. L. Sammet and D. G. Malcolm, "Work Sampling Studies: Guides to Analysis and Accuracy Criteria," Journal of Industrial Engineering, Vol. 5, No. 4 (July, 1954), p. 9.

Large quantities of data were also obtained from plant operating records. These data included the amount canned daily by individual workers in relation to their position along the canning belt. Additional information was obtained relating to the daily size distribution, daily volume of canned output, and number of hours worked per day for both green and white asparagus spears.

Statistical Analysis

Preliminary analyses of work measurement and plant production data indicated that productivity of any individual canner is greatly influenced by the volume of asparagus spears delivered to the canning belt (line-load), the position or location of the canner from the beginning of the line, and the size distribution of the asparagus spears being canned. A simple regression technique was employed initially to estimate gross relationships among some of the above variables. The following least-squares regression equations were computed for green and white asparagus:

Green asparagus

$$Y_{g,ij} = 1.57107 + 0.01698(L_i) - 0.15711(P_j) \quad (1)$$
$$(0.00261) \quad (0.00575)$$
$$\bar{R}_g^2 = 0.778$$

White asparagus

$$Y_{w,kj} = 1.61799 + 0.01666(L_k) - 0.16177(P_j) \quad (2)$$
$$(0.00287) \quad (0.00634)$$
$$\bar{R}_w^2 = 0.658$$

where

$Y_{g,ij}$ = number of No. 300 can-size equivalents per canner per minute, green asparagus spears.

$Y_{w,kj}$ = number of No. 300 can-size equivalents per canner per minute, white asparagus spears.

L_i = line-load in average number of No. 300 can-size equivalents of
canning quality green asparagus spears per canner hour, where
 $80 \leq L_i \leq 110$

L_k = line-load in average number of No. 300 can-size equivalents of
canning quality white asparagus spears per canner hour, where
 $130 \leq L_k \leq 190$

P_j = location or position of pairs of canners from the beginning of
the canning line where $1 \leq P_j \leq 18$

and

numbers in parentheses are the standard errors of the respective
coefficients.

In comparing the above equations, it should be noted that the line-load
variables L_i and L_k incorporate different parameter constraints, and therefore
the equations are valid only for the range in line-loads specified. Nevertheless,
the close correspondence of the line-load and the close correspondence of
the position coefficients indicate that the rate of change in canner output with
respect to a change in line-load and canner position is essentially the same for
both green and white asparagus.

It is convenient to use the reciprocals of equations (1) and (2) for determining the time to can one No. 300 can-size equivalent of green and white asparagus. The reciprocal form of these equations will also be used for graphic analyses so as to assist the reader in understanding the relationship between time to can and worker position.

A three dimensional illustration of the relationships between line-load, the position of the canner, and time to can for a single-size distribution of white asparagus spears is shown in Figure 2. As paired canner positions increase, time to can per worker increases at an increasing rate. In addition, time to can per worker increases at an increasing rate as line-load is decreased. At point o, the plane op cuts through the three line-loads and extends vertically to identical total output planes, such as the horizontal plane defg. The line segment ki

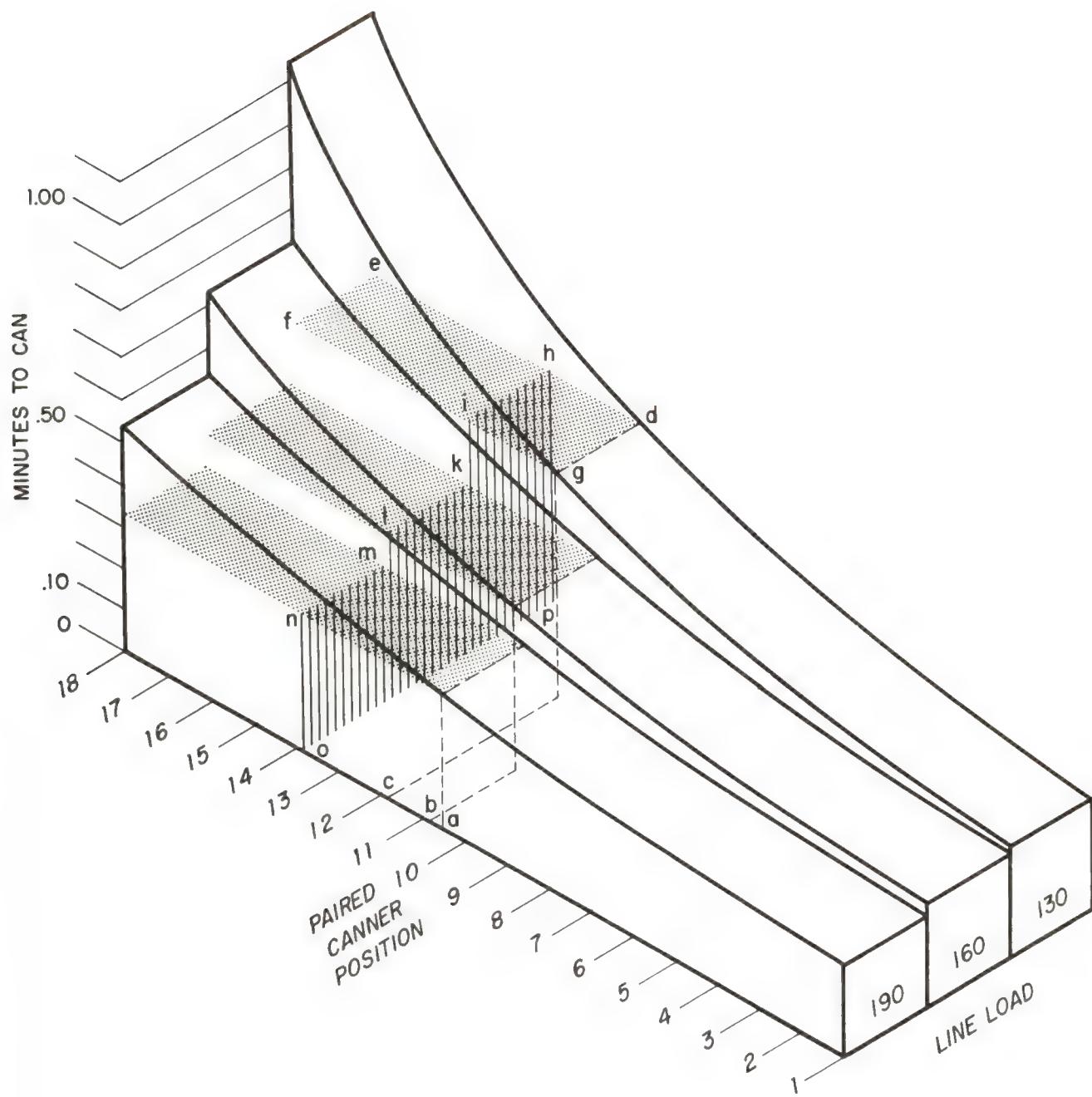


Figure 2. Minutes Required Per Canner to Can a No. 300 Can-Size Equivalent of White Asparagus Spears in Relation to Line Position and Selected Line-Loads Based on a Three-Variable Statistical Model, California, 1964.

shows the differences in times to can for line-loads 130 and 160 for a constant output of commodity at point o. Points a, b, and c in this figure illustrate the differences in the number of cannery required to can a particular total output when line-load is varied.

From the simple equations given above, it is not possible to estimate the effect on canner output of size distribution nor the effect of possible interactions among the variables representing line-load, position of the canner, and size. For these reasons, a more comprehensive model is required. An analysis based on a more completely specified model is presented in the next section. As data relating to size distributions of green asparagus are not available in amounts and detail required, the analysis deals primarily with white asparagus.

A General Model

The simple prediction model discussed above fails to include several important variables and their interactions that are required for a more complete analysis of the utilization of asparagus canning labor.

First, canner output rates for any given section of the canning belt are affected by the appearance or elimination of a specific size category. Cannery generally pack the largest spears available to them, and this parameter varies not only with changes in the proportions of particular sizes but also with changes in line-load. Any canner working in an area of frequent size fluctuation could have a decrease in productivity in excess of that caused by normal line-load changes along the belt. Productivity in these areas is affected by the increase in the number of decisions a canner must make in selecting alternative size blends. The frequency with which cannery in different line positions are employed in packing different sizes is shown in Table 2. Cannery at position 4, for example, were engaged in packing size index 65 three times, size

TABLE 2

Number of Man-Days in Relation to Spear Size Index and Canner Position
 and Number of Cans Observed Per Position for White Asparagus
 California, 1964

Paired canner position	Man-days by spear size index						Total	Number of cans in sample
	65	77	100	155	245	271		
1	13	1	a/				14	24,157
2	11	3					14	22,923
3	7	7					14	19,968
4	3	8	3				14	18,658
5		10	4				14	20,865
6		10	4				14	18,181
7		8	6				14	16,333
8		6	8				14	15,421
9		3	11				14	15,663
10		2	11	1			14	14,542
11		2	8	4			14	13,115
12		2	6	6			14	11,931
13		1	4	9			14	11,174
14			4	9	1		14	11,018
15			2	8	4		14	10,896
16			2	3	9		14	9,153
17			1	1	11	1	14	9,512
18				2	5	7	14	8,358
19				1	2	11	14	6,930
Total	34	63	74	44	32	19	266	278,798

a/ Blanks denote zero.

index 77 eight times, and size index 100 three times. Canners in positions 1-3 packed only size indexes 65 and 77.

Second, differences in worker productivity by position might be partly due to daily or periodic changes in canner position resulting from the management's policy of rotating cannery workers.

Third, an empirical formulation should include a basis for estimating interrelationships among the variables line-load, proportions of specific spear sizes or size blends, and the position of the canner in relation to the beginning of the line.

Fourth, as mentioned above, the number of cannery workers employed per belt ranged from 38 to 42 and remained nearly constant during the peak periods. Consequently, the statistical analysis is necessarily based on a crew of a given size.

Data relating canner output in terms of No. 300 can-size equivalents to average hourly line-loads and size distributions were obtained from plant records for a sample of 14 days during the operating season. Dummy or indicator variables were used to incorporate interactions among these variables in the model.^{1/}

The regression equation finally formulated is given in equation (3) below.^{2/} In this expression, canner productivity is expressed in terms of the number of No. 300 can-size equivalents per canner minute.

$$Y_{ijkqm} = 0.86533 + 0.01789(L_{ijqm}) - 0.00796(S_{ijqm}) + b_{2,q}^* + b_{3,i,q}^* + b_{4,m}^* \quad (3)$$
$$R^2 = 0.738$$

^{1/} For details regarding the use of dummy variables in regression analysis, refer to J. Johnston, Econometric Methods (New York: McGraw-Hill Book Company, 1963), 300p.

^{2/} The problem was programmed for the IBM 1620 by Dr. James N. Boles of the University of California. For additional details, refer to James N. Boles, 80-Series Multiple Linear Regression System, 6.0143 (New York: IBM, 1620 General Program Library, 1964), 491p.



(ERRATA)

Some Aspects of Land Appraisal in Southern California (Part I)

by

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California Agricultural Experiment Station
Division Foundation of Agricultural Research

In cooperation with

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Economic Research Service, U.S.D.A.

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where

- Y = cans per canner minute in No. 300 can-size equivalents.
- L = line-load in average number of No. 300 can-size equivalents per canner hour.
- S = size index of spear diameter by canner position.
- i = 1, ..., 19 measured in pairs of cannerys from the beginning of the line.
- j = 130, ..., 190 in average number of No. 300 can-size equivalents of canning quality white spears per canner hour.
- k = 65, ..., 271 as a measure of spear size index.
- q = 65, 77, 100, 155, 245, or 271 (discrete).
- m = 1, ..., 7 in days.
- $b_{1,i}^*$ = indicator (or dummy) variable set up to represent the entry (1) or lack of entry (0) of a particular position i ; that is, $b_{1,1}^*$ is the effect on Y of position 1, $b_{1,2}^*$ is the effect on Y of position 2, etc. The asterisk indicates position ($i = 19$) dropped in the dummy variable procedure. For example, the original effects were labeled $b_{1,1}^*$ through $b_{1,19}^*$, and then $b_{1,19}^*$ was set equal to zero to avoid singularity in the matrix inversion.
- $b_{2,q}^*$ = indicator (or dummy) variable set up to represent the entry (1) or lack of entry (0) of a particular size index q . $b_{2,65}^*$ is the effect on Y of the discrete size $q = 65$, $b_{2,77}^*$ is the effect on Y of the discrete size $q = 77$, etc. The asterisk indicates size $q = 271$ dropped in the dummy variable procedure.
- $b_{3,i,q}^*$ = indicator (or dummy) variable set up to represent the entry (1) or lack of entry (0) of size q , given position i . $b_{3,1,65}^*$, for example, is the joint effect on Y of discrete size $q = 65$ and position $i = 1$. The asterisk indicates one discrete size category ($q = 271$) dropped in the dummy variable procedure.
- $b_{4,m}^*$ = indicator (or dummy) variable representing a given day from which the observations were drawn, with the asterisk indicating the elimination of one of the days in line with the dummy variable procedure.

Characteristics of the general formulation are shown in Table 3. Standard errors and t ratios of the coefficients of the 61 variables are given in Appendix Table 1.

TABLE 3
Characteristics of the General Model for White Asparagus
California, 1964

Item	Value
Sample size in number of cans	278,798
Number of day-position observations	266
Standard error Y·X	0.68331
R^2	0.73835
Sum of squares, residual	98.05368
Total variables	61

Coefficients for the b^* variables are given in Table 4. This table also shows the position-size interaction terms that are applicable for each segment of the canning line.

The use of equation (3) to estimate canner productivity requires substitution of specific values for line-load and size index and applying the results to the appropriate coefficients of the b^* variables given in Table 4. For example, to calculate the rate of canner output per minute in No. 300 can-size equivalents of colossal asparagus spears (size index 65) for the fourth pair of canners, assuming an average line-load of 160 cans per worker hour, involves the substitution of the following values for the variables in equation (3).

$$\begin{array}{ll}
 L_{ijqm}^* = 160 & b_{2,65}^* = -1.14155 \\
 S_{ijqm}^* = 65 & b_{3,4 \cdot 65}^* = 0.65902 \\
 b_{1,4}^* = 0.42817 & b_{4,3}^* = 0
 \end{array}$$

TABLE 4

Coefficients and Interaction Term by Spear Size Index and
 Canner Position According to the Size of Asparagus
 for the General Model for White Asparagus
 California, 1964

Variables by groups	Variable coefficients	Interaction term by spear size index					
		65 (1)	77 (2)	100 (3)	155 (4)	245 (5)	
<u>Canner position</u>							
<u>b[*]</u> b _{1,i} where i =							
1	2.22535	1.1	1.2	<u>a/</u>			
2	b/	2.1	2.2				
3	0.50794	3.1	3.2				
4	0.42817	4.1	4.2	<u>--c/</u>			
5	1.44669		5.2	--			
6	0.07169		6.2	--			
7	b/		7.2	--			
8	-0.13500		8.2	--			
9	-0.00324		9.2	--			
10	1.78211		10.2	10.3	--		
11	1.80346		11.2	11.3	--		
12	2.07057		12.2	12.3	--		
13	1.83890		13.2	13.3	--		
14	0.84917			14.3	14.4	--	
15	1.34302			15.3	15.4	--	
16	1.20904			16.3	16.4	--	
17	0.18681			17.3	17.4	17.5	
18	-0.02829			18.3	18.4	18.5	
<u>Size</u>							
<u>b[*]</u> b _{2,q} where q =							
65	-1.14155						
77	-0.11636						
100	b/						
155	-2.27949						
245	-1.14951						
271	b/						
<u>Position-size</u> <u>interaction term</u>							
<u>b[*]</u> b _{3,i·q} where i·q =							
1·1	b/						
2·1	2.37597						
3·1	1.10374						

(Continued on next page.)

TABLE 4--continued.

Variables by groups	Variable coefficients	Interaction term by spear size index				
		65 (1)	77 (2)	100 (3)	155 (4)	245 (5)
4.1	0.65902					
4.2	-0.00147					
5.2	-0.93558					
6.2	0.30141					
7.2	-0.07334					
8.2	-0.15075					
9.2	-0.64288					
10.2	-2.17198					
10.3	-2.06046					
11.2	-2.67833					
11.3	-2.18227					
12.2	-3.07045					
12.3	-3.00303					
13.2	-2.42878					
13.3	-3.05174					
14.3	-1.85205					
14.4	0.95559					
15.3	-3.09078					
15.4	0.54329					
16.3	-3.37680					
16.4	0.08647					
17.3	-2.45457					
17.4	0.98311					
17.5	0.97681					
18.4	0.22322					
18.5	1.18842					
<u>Day</u>						
$b_{4,m}^*$ where $m =$						
1	0.24204					
2	-0.03134					
3	b/					
4	0.06250					
5	-0.01211					
6	-0.02712					

a/ Blanks denote zero.

b/ Coefficient dropped due to insignificance.

c/ Dashes indicate for listed interaction position where no interaction coefficient is available, use remaining pertinent coefficients.

Substitution of the above values in equation (3) gives:

$$\begin{aligned} Y_{4,65} &= 0.86533 + 0.01789(160) - 0.00796(65) + 0.42817 - 1.14155 + 0.65902 \\ &= 3.15597 \text{ cans of colossal spears (size index 65) per minute for each worker located at position 4.} \end{aligned}$$

To estimate the minutes required to can one No. 300 can-size equivalent of colossal spears (equation 4), the reciprocal procedure would be as follows:

$$\frac{1}{Y_{4,65}} = \frac{1}{3.15597} = 0.3168 \text{ minutes per can per worker.}$$

Similar computations are involved in estimating canner output for each of the different size categories canned at a particular line position. Table 2 shows, for example, that canners at position 4 also packed a colossal/mammoth blend (size index 77) and a mammoth/large blend (size index 100). Carrying through the appropriate substitutions gives the following canner outputs for size indexes 77 and 100. For size index 77, the calculations are:

$$\begin{aligned} Y_{4,77} &= 0.86533 + 0.1789(160) - 0.00796(77) + 0.42817 - 0.11636 - 0.00147 \\ &= 3.42515 \text{ cans per worker minute for each worker at position 4 when engaged in packing a colossal/mammoth blend.} \end{aligned}$$

For size index 100:

$$Y_{4,100} = 3.35990 \text{ cans per worker minute for each worker at position 4 when engaged in packing a mammoth/large blend.}$$

The corresponding values in terms of time to can are 0.2919 for size index 77 and 0.2976 minutes per can of size index 100.

The data in Table 2, showing the frequency with which canners located at different line positions were observed packing a particular size category, may be used to calculate a weighted average of canner productivity by position. Using the frequencies given in Table 2 as weights, the weighted average for all sizes canned at position 4 is computed as follows:

$$\bar{Y}_{w_4} = \frac{[3.15597(3) + 3.42515(8) + 3.35990(3)]}{14} = 3.35349 \text{ cans per worker per minute.}$$

In terms of minutes to can:

$$\frac{1}{\bar{Y}_{w_4}} = \frac{1}{3.35349} = 0.2982 \text{ minutes per worker per can.}$$

Following the procedures outlined above, canner productivity in terms of cans per worker minute (Y_{w_i}) or in minutes per can per worker ($\frac{1}{Y_{w_i}}$) may be calculated for any given line position, size index, and line-load that lies within the constraints of the model. Estimates of canner output per worker minute (Y_{w_i}) were calculated for 18 pairs of workers, 4 line-loads, and 5 size categories.

Several general characteristics of canner productivity are indicated in Table 5. First, output rates per canner for any given size decrease as the position of the canner from the beginning of the line is increased. Second, output rates of successive cannery along the line are affected by changes in the proportions of particular sizes that are available. For example, cannery in position 4 are influenced by the lack of colossal (size index 65) and the presence of mammoth and large spears. These characteristics are also reflected in the weighted average output rates (\bar{Y}_{w_i}) shown in Table 5. Relatively large fluctuations in canner productivity are noted for cannery located at line positions 4, 10, 14, and 17. At these positions canner output decreases due to interrelationships among the number of spears and proportions among the size categories available.

Weighted average times to can ($\frac{1}{\bar{Y}_{w_i}}$), corresponding to the estimates (\bar{Y}_{w_i}) given in Table 4 were also calculated. The results for three selected line-loads are graphically depicted in Figure 3. The effects on minutes required to pack a No. 300 can-size equivalent are clearly illustrated in this figure.

Table 5

300 Can-size Equivalents Per Canner Minute With Respect to The Position
of The Canner, Size of Asparagus, and Selected Line-loads Derived From
The General Model, White Asparagus, California, 1964

Line-load 130							Line-load 150						
Paired Canner Position	Spear Size Index					Weighted Average $1/Y_{wi}$	Paired Canner Position	Spear Size Index					Weighted Average $1/Y_{wi}$
	65	77	100	155	245			65	77	100	155	245	
	Cans Per Canner Minute							Cans Per Canner Minute					
1	3.75743	4.68710				3.82384	1	4.11523	5.04490				4.18164
2	3.90805	2.46175				3.59813	2	4.26585	2.81955				3.95593
3	3.14376	2.96969				3.05672	3	3.50156	3.32749				3.41453
4	2.61927	2.88845	2.82320			2.81678	4	2.97707	3.24625	3.18100			3.17459
5		2.97286	3.84172			3.22110	5		3.33066	4.19952			3.57891
6		2.83485	2.46672			2.72967	6		3.19265	2.82452			3.08747
7		2.38841	2.39503			2.39125	7		2.74621	2.75283			2.74905
8		2.17600	2.26003			2.22402	8		2.53380	2.61783			2.58182
9		1.81563	2.39179			2.26833	9		2.17343	2.74959			2.62613
10		2.07188	2.11668	1.45985		2.06336	10		2.42968	2.47448	1.81765		2.42116
11		1.58688	2.01622	1.48120		1.80202	11		1.94468	2.37402	1.83900		2.15982
12		1.46188	1.46258	1.74832		1.58494	12		1.81968	1.82038	2.10612		1.94274
13		1.87187	1.18219	1.51664		1.44646	13		2.22967	1.53999	1.87444		1.80426
14			1.39215	1.48250	0.94046	1.41797	14			1.74995	1.84030	1.29826	1.77577
15			0.64727	1.11405	1.43434	1.13888	15			1.00507	1.47185	1.79214	1.49668
16			0.22727	0.97325	1.30036	1.07697	16			0.58507	1.33105	1.65816	1.43477
17			0.12727	0.84766	1.25494	1.12750	17			0.48507	1.20546	1.61274	1.48530
18					1.25145	0.99786	18			0.23047	1.60925		1.28940
Line-load 160							Line-load 190						
1	4.29413	5.22380				4.36054	1	4.83083	5.76050				4.89724
2	4.44475	2.99845				4.13483	2	4.98145	3.53515				4.67153
3	3.68046	3.50639				3.59343	3	4.21716	4.04309				4.13013
4	3.15597	3.42515	3.35990			3.35349	4	3.69267	3.96185	3.89660			3.89019
5		3.50956	4.37842			3.75780	5		4.04626	4.91512			4.29451
6		3.38155	3.00342			3.27351	6		3.90825	3.54012			3.80307
7		2.92511	2.93173			2.92795	7		3.46181	3.46843			3.46465
8		2.71270	2.79673			2.76072	8		3.24940	3.33343			3.29742
9		2.35233	2.92849			2.80503	9		2.88903	3.46519			3.34173
10		2.60858	2.65338	1.99655		2.60006	10		3.14528	3.19008	2.53325		3.13676
11		2.12358	2.55292	2.01790		2.33872	11		2.66028	3.08962	2.55460		2.87542
12		1.99858	1.99928	2.28502		2.12164	12		2.53528	2.53598	2.82172		2.65834
13		2.40857	1.71889	2.05334		1.98316	13		2.94527	2.25559	2.59004		2.51986
14			1.92885	2.01920	1.47716	1.95467	14			2.46555	2.55590	2.01386	2.49137
15			1.18397	1.65075	1.97104	1.67558	15			1.72067	2.18745	2.50774	2.21228
16			0.76397	1.50995	1.83706	1.61367	16			1.30067	2.04665	2.37376	2.15037
17			0.66397	1.38436	1.79164	1.66420	17			1.20067	1.92106	2.32834	2.20090
18				0.40937	1.78815	1.46830	18			0.94607	2.32485		2.00500

1/ Weighted by the number of times cannery in given positions were observed packing a particular size of asparagus spear. See Table 2 for the specific weights used.

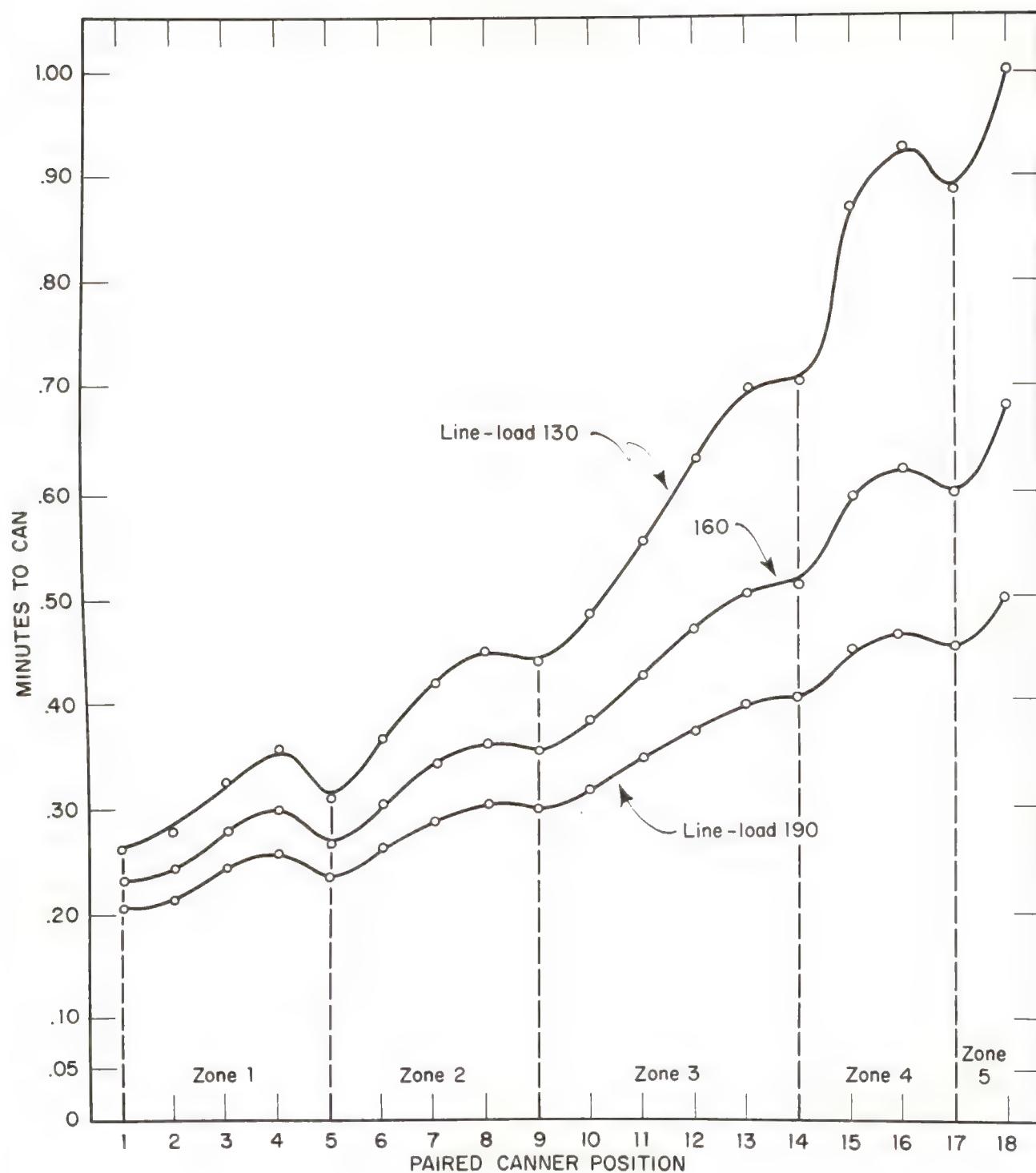


Figure 3. Weighted Average Unit Times For No. 300 Can-Size Equivalents Showing Zones of Productivity in Relation To Line Position and Selected Line-Loads, California, 1964.

Interrelationships among position, size, and line-load are so pronounced that it is possible to segment canner's position into five zones. The boundaries of each zone identify the line positions where changes in proportions of sizes available along with an increased number of decisions result in relatively large changes in canner productivity.

The effect that changes in line-load have on time to can, per worker, for a given canning crew is also indicated in Figure 3. For example, the figure shows that time to can for position 10 is about 0.5 minute per can for an average line-load of 130 cans per worker. This time decreases to about 0.4 minute per can with a line-load of 160 and accounts for only 0.3 minute per can for a line-load of 190 cans per worker hour.

The presence of the zones and time-to-can fluctuations described above were investigated further to ascertain which particular elements within the canner's work operation were being affected by the spear size, line-load, and canner's position constraints. Work measurement studies were conducted to allow the conversion of element times into percentages of the total time to can one No. 300 can-size equivalent.

Work measurement studies of belt asparagus canning operations explained the reasons for a time-to-can function which increased at an increasing rate as canners are added to the line. Each canner's operation was divided into the following six work elements: secure empty can,^{1/} select asparagus spears, fill can, place full can aside onto a moving conveyor, perform miscellaneous operations excluding wait time, and wait for asparagus of either proper size or sufficient volume.

1/ Stamping the can for size of pack is included within this operation.

The two major work elements observed in manual canning operations were the select and fill can elements. The select element can include a certain amount of wait time since the canner can be actively looking for asparagus spears of a distinct size range without selecting for quality of pack. Each element, as a percent of total time to can a single can, is shown in Table 6 for all canning positions observed in plants with nearly identical canning operations. The variations shown between element percentages in Table 6 reflect, mainly, differences among plants studied and line-loads during days of observation.

In addition to the fluctuations of element proportions shown in Table 6, the work measurement studies were concerned with possible changes in these proportions with respect to changes in the position of the canner. Canning lines were divided into segments of three pairs of workers per segment. A listing of element proportions by line segments can be found in Table 7. Selection times for green and white asparagus were found to increase at a rate of:

$$S_{g_i} = 53.23 + 5.46 (X_i); r_g^2 = 0.963 \quad (4)$$

$$S_{w_i} = 50.99 + 4.57 (X_i); r_w^2 = 0.746 \quad (5)$$

where

S_{g_i} = percentage of selection time for green asparagus with respect to total time.

S_{w_i} = percentage of selection time for white asparagus with respect to total time.

X_i = line segment of three pairs of canners, as $1 \leq X_i \leq 6$.

The increase in the percentage of selection time shown in equation (5) reflects both wait time for the proper size of asparagus spear as well as decreases in line-load as X_i ranges from one to six segments.

TABLE 6

Canners' Time, by Work Element, and Average of All Canner Positions
as a Percentage of Total Time for Canning Green and White Asparagus
California, 1964

Work element	White asparagus ^{a/}			Green asparagus ^{a/}		
	Plant			Plant		
	1	2	3	4	5	6
percent						
Secure empty	6.7	6.6 ^{b/}	5.1	2.6	6.8 ^{b/}	3.5
Select	69.3	66.1	59.5	76.5	70.7	67.9
Can	17.4	18.8	23.2	15.8	16.4	22.5
Set aside full	6.3	6.0	7.1	2.4	5.0	5.1
Miscellaneous	0.3	2.2	0.4	1.4	0.7	0.6
Wait	0	0.3	4.7	1.3	0.4	0.4
Total	100.0	100.0	100.0	100.0	100.0	100.0

^{a/} Each plant represents 750 to 3,340 individual observations with plants using similar techniques.

^{b/} Includes marking the can for size of pack.

TABLE 7

Canners' Time, by Type of Asparagus and Work Element, as a Percentage
 of Total Time for Canning Green and White Asparagus
 by Group of Paired Canner Positions
 California, 1964

Type of asparagus and work element	Paired canner position					
	1-3	4-6	7-9	10-12	13-15	16-18
	percent					
<u>White</u>						
Secure empty ^{a/}	5.5	8.4	4.1	4.9	1.4	1.2
Select	56.7	54.6	69.2	72.3	70.7	30.5
Can	29.5	26.0	16.7	16.3	10.0	4.9
Set aside full	7.7	10.1	10.0	5.5	1.4	2.4
Miscellaneous	0.5	0.3	0	0.5	0	0
Wait	0.1	0.6	0	0.5	16.5	61.0
Total	100.0	100.0	100.0	100.0	100.0	100.0
<u>Green</u>						
Secure empty ^{a/}	4.3	4.3	3.4	2.9	2.2	1.5
Select	56.1	66.2	69.6	77.3	80.8	84.0
Can	31.6	24.2	21.0	14.9	13.0	10.1
Set aside full	7.2	5.1	4.6	4.1	3.1	2.2
Miscellaneous	0.8	0.2	1.2	0.4	0	0.5
Wait	0	0	0.2	0.4	0.9	1.7
Total	100.0	100.0	100.0	100.0	100.0	100.0

^{a/} Includes marking the can for size of pack.

Productive canning element times for green and white asparagus decreased at the rates of:

$$F_{g_i} = 33.85 - 4.21 (X_i); \quad r_g^2 = 0.962 \quad (6)$$

$$F_{w_i} = 34.73 - 4.90 (X_i); \quad r_w^2 = 0.969 \quad (7)$$

where

F_{g_i} = percentage of canning element time for green asparagus spears

F_{w_i} = percentage of canning element time for white asparagus spears

X_i = line segment of three pairs of canners, as $1 \leq X_i \leq 6$

and

numbers in parentheses are standard errors of the respective coefficients.

The differences between equations (6) and (7) reflect the relatively larger average diameter of white asparagus spears; thus the faster decrease in line-load in relation to successive line position.

A Computational Model

The general model for white asparagus developed in the preceding section provides a relatively detailed basis for explaining direct and interrelated effects of the variables considered on canner productivity. The direct and joint effects of the variables formulated in equation (3) cause canner output rates to fluctuate at certain line positions. The nature and extent of these effects are shown by the humps of the curves in Figure 3.

Because of the large number of computations involved, calculation of canner output rates and unit times for the various line positions, sizes of spears, line-loads, and interaction terms becomes tedious and time consuming. A less elaborate computational model may be used to allow greater ease in manipulating

the principal variables affecting labor productivity in manual canning operations. It consists of a four-variable regression equation relating individual canner output (or time to can) to the size of asparagus, line position of canners, and line-load. The equation was fitted to 329 computed values derived from the general model as formulated in equation (3). Coefficients of the indicator or dummy variables (b^* 's) of equation (3) are, therefore, bound inside one or more of the variables of the computational model; consequently, the computational model is valid only within the constraints of the general formulation. The regression equation given below, representing a simplified version of the general model, will provide the basis for calculating and illustrating the estimates and relationships to be presented in this section.^{1/}

Estimates in the variability of canning labor productivity from the four-variable multiple-regression analysis is:

$$C_{ijk} = 1.28199 + (0.00370)Z_{1,i} - (0.20625)Z_{2,j} + (0.01789)Z_{3,k} \quad (8)$$

$$\bar{R}^2 = 0.870$$

^{1/} The equation shows the average relationship of canner output rates to the variables specified. It is computed to minimize the sum of the squared residuals between the canner output rates represented by the equation and the calculated values obtained from equation (3). The adjusted multiple-correlation coefficient of 0.870 indicates that the computational equation gives a close fit of the rates predicted by equation (3). It does not, however, provide a statistical measure of the validity of these precomputed estimates. A corresponding four-variable regression analysis from the basic data yielded the following equation:

$$C_{ijk}^* = 1.42819 + (0.00355)Z_{1,i} + (-0.19729)Z_{2,j} + (0.01720)Z_{3,k}$$

$$(0.00115) \quad (0.01422) \quad (0.00169)$$

$$\bar{R}^2 = 0.68553$$

where the numbers in parentheses are standard errors of the respective coefficients. Since C_{ijk}^* does not differ significantly from C_{ijk} and has a lower correlation coefficient with respect to the original data--and, therefore, equation (3)--equation (8) will be used for prediction purposes.

where

C_{ijk} = number of No. 300 can-size equivalents per worker per minute.

$Z_{1,i}$ = size of asparagus spears, as $65 \leq Z_{1,i} \leq 271$.

$Z_{2,j}$ = paired canner positions, as $1 \leq Z_{2,j} \leq 18$.

$Z_{3,k}$ = line-load in average number of No. 300 can-size equivalents per worker hour, as $130 \leq Z_{3,k} \leq 190$.

Equation (8) can be readily used for production prediction purposes. Assuming certain line-loads, as well as the proportions of each size of asparagus to be canned, management can determine the average time to can (or average labor cost per can).

The sign of the $Z_{1,i}$ coefficient should be mentioned since it incorporates the effects of certain canners changing from one size of asparagus spear to another. As i approaches its highest bounds, the value of C_{ijk} tends toward zero. This fact, at first inspection, might seem to be an incorrect relationship. The sign of the $Z_{1,i}$ coefficient must be analyzed in relation to the slopes of the output rates per spear size as $Z_{2,j}$ approaches its upper limit. At any position, j , where the canner has the opportunity to can, say, both size index 77 and the next smaller size, the smaller sized spear will take less time to can since there is a greater positional line-load of the smaller size available to can.

This relationship can be seen in Figure 4. The steps for each size index in the figure illustrates the greater time requirements as line position increases, while the steps for each position show the size-position interaction. For example, at paired worker position 13, spear size indexes 77, 100, or 155 may be canned depending upon the relative percentages of these sizes being delivered to the canning belt. The unit times to can one No. 300 can-size equivalent at position 13 would be either 0.572, 0.546, or 0.491 for spear size indexes 77, 100, and 155, respectively. Calculations showing the specific values on which Figure 4 is based are summarized in Table 8 for those interested in detailed numerical comparisons.

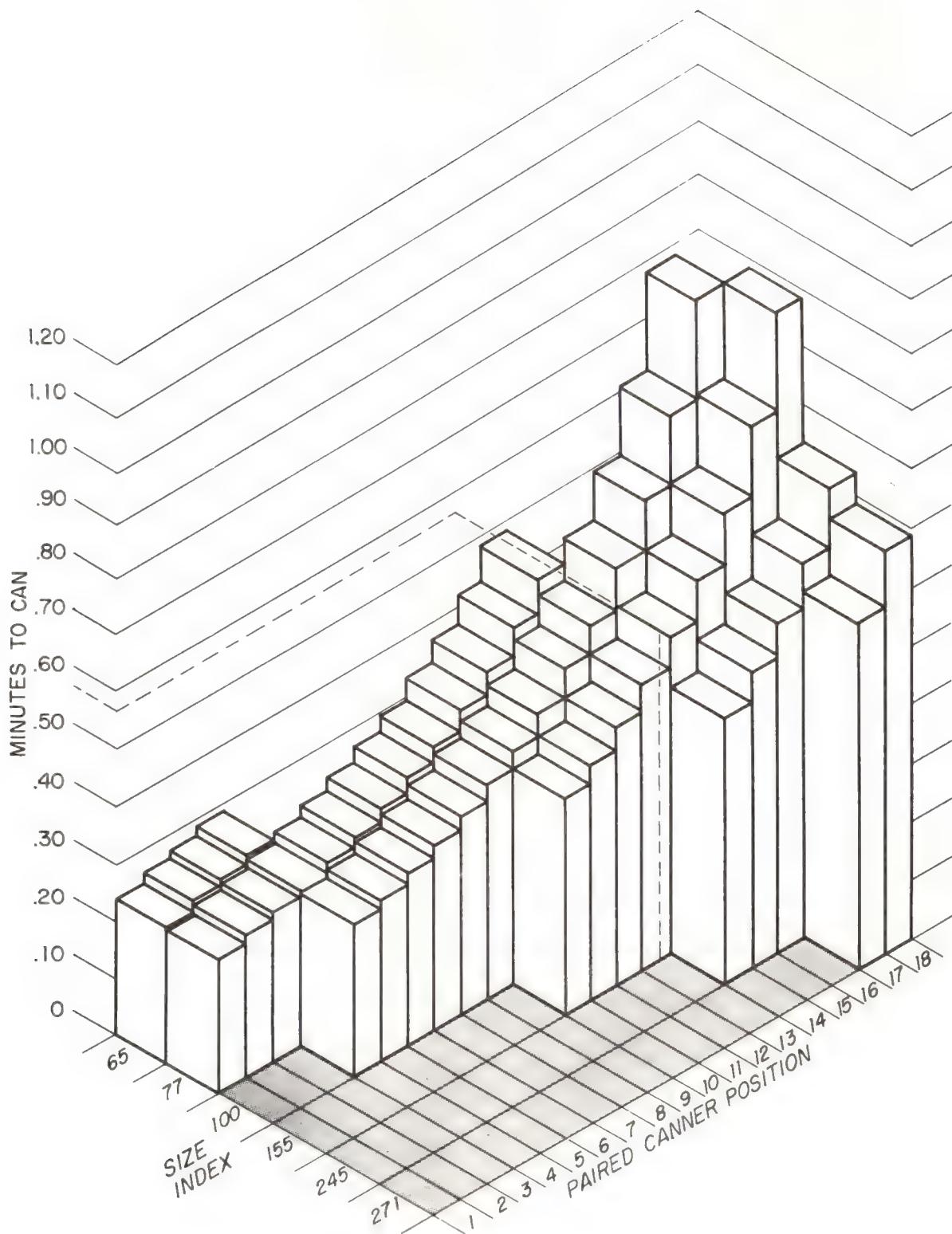


Figure 4. Minutes Required to Can a No.300 Can-Size Equivalent of Asparagus in Relation to Spear Size Index and Paired Canner Positions for an Average Line-Load of 160 Cans Per Canner Hour, California, 1964.

The effect of a decreasing supply of a particular size of asparagus spear is to reduce canner productivity at those positions where this consequence is relevant. Figure 5 shows linear slopes for each particular size listed in Table 8. In addition, Figure 5 shows the weighted average output rate of the general model for white asparagus. The shaded areas in this figure illustrate canner production lost when the proportions of a particular size vary at successive line positions.

Canning labor costs vary a great deal with changes in line-load and worker position. With a basic wage of \$2.24 per hour, the cost per can at position 1 varies from 0.0102 cent to 0.0079 cent when line-load changes from 130 to 190 cans per worker hour.^{1/} At a line-load of 130 cans per worker hour, per can labor costs range from 0.0102 cent to 0.0416 cent as paired canner position is varied from 1 to 18.

Presized Asparagus

This section of the report deals with the effects of labor utilization when an automatic asparagus sizer is used in conjunction with belt canning operations. The asparagus sizing equipment can be divided into two main sections: a feed section and a sizing section. The feed section is a spear distributing area which, through the incorporation of vibrators and/or water flow, distributes the asparagus spears onto the sizing section. The sizing section is composed of parallel stainless steel sizing rods of varying diameters which size the spears into four major classifications: 6/16 inch and under, 6/16 to 10/16 inch, 10/16 to 14/16 inch, and 14/16 inch and over in diameter. The exact parameters of these four classifications can be predetermined by plant management through the adjustment

^{1/} Based on a wage rate of \$2.04 per hour plus 10 percent to cover employer payroll contributions and other fringe benefits.

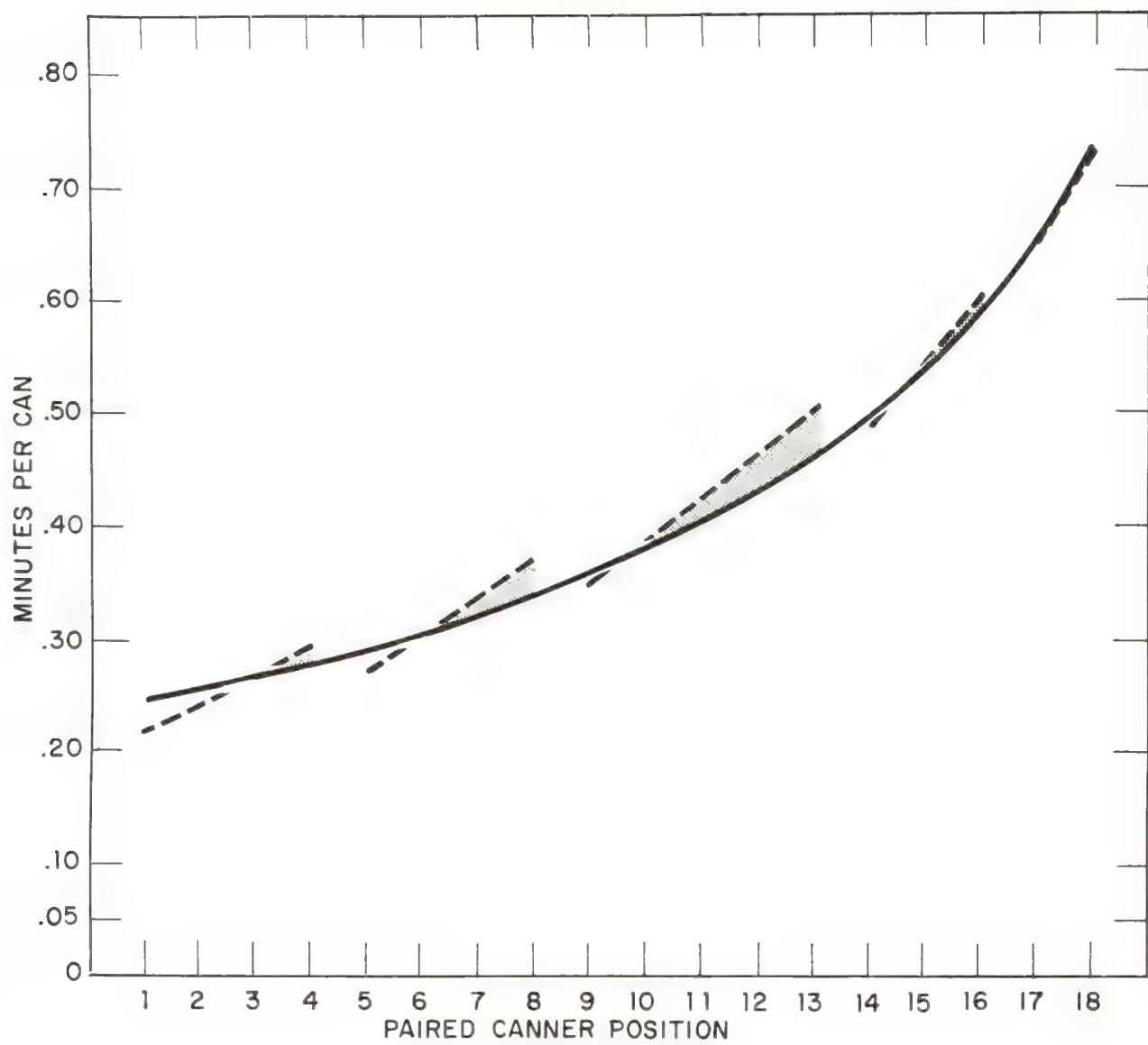


Figure 5. Time to Can White Asparagus Spears With Respect to Paired Canner Positions for the Computational Model for an Average Line-Load of 160 Cans Per Canner Hour, California, 1964.

TABLE 8

Minutes Per No. 300 Can-Size Equivalent for Canning White Asparagus
 by Paired Canner Position and Spear Size Index
 for a Line-Load of 160 Cans Per Canner Hour
 California, 1964

Paired canner position	Minutes per can by spear size index						Weighted average $(\frac{1}{Y_{wi}})$
	65	77	100	155	245	271	
1	0.239	0.237	a/				0.239
2	0.252	0.249					0.251
3	0.265	0.262					0.263
4	0.281	0.277	0.271				0.277
5		0.294	0.287				0.292
6		0.313	0.305				0.311
7		0.335	0.326				0.331
8		0.360	0.349				0.354
9		0.389	0.376				0.379
10		0.422	0.408	0.377			0.408
11		0.463	0.445	0.408			0.437
12		0.512	0.490	0.446			0.474
13		0.572	0.546	0.491			0.512
14			0.615	0.546	0.462		0.560
15			0.704	0.616	0.511		0.599
16			0.823	0.705	0.571		0.636
17			0.992	0.824	0.647	0.609	0.682
18				0.995	0.747	0.697	0.757

a/ Blanks denote zero.

of the sizing rollers. Capacities of asparagus sizers at the time this study was conducted were rated at from 4,000 to 12,000 pounds of spears per hour, depending upon the manufacturer and the size of the unit.

In discussing the effects of the presized method of asparagus canning, the size variable s_i varies from 65 to 271 as was the case in the general and computational models. To reduce the number of size combinations which otherwise would be considered, it is assumed that s_i possesses the following discrete proportions which were typical of the proportions observed: $s_{65} = 12.8$ percent of the total line load; $s_{77} = 23.7$ percent; $s_{100} = 27.9$ percent; $s_{155} = 16.5$ percent; $s_{245} = 12.0$ percent; and $s_{271} = 7.1$ percent of the total line-load.

With respect to the number of canning lines utilized, numerous presizing models can be presented. Some of these options will be included in a later report. For purposes of the current analysis, the number of canning lines will be established by predetermined operating characteristics of the automatic sizer. It is assumed that four size categories will be obtained from the sizer and that these sizes will exhaust total line-load. With regard to subsizing by visual inspection of the canners, it is further assumed that this condition will not occur.^{1/} Therefore, this section of the report deals with limited blend packs, and these limits may be modified at the discretion of the plant management by adjusting the automatic sizer.

The spear diameters listed in Table 9 allow discussion of a plant with three canning belts operating from a single sizer.^{2/} Belt number 1 will be used

^{1/} Subsizing does not include sizing due to possible malfunctioning or overloading of the sizing equipment. Possible exceptions which do not affect this analysis are when size index 271 is less than 4/16 inch and when size index 65 is in excess of 1 inch in diameter.

^{2/} Sizers can be combined to deliver onto the same canning belts thus increasing the line-load of each belt.

to can size index 77 only. This belt would handle approximately 24 percent of the total line-load.

Canning belt number 2 transports size indexes 271, 245, and 65, accounting for approximately 32 percent of the total line-load. Size indexes 271 and 245 will be delivered on the same side of this canning belt. Fluming arrangements from the sizer can be constructed in such a manner that size indexes 271 and 245 will be either deposited on the canning belt or conveyed to Urschel-type cutters.

Canning belt number 3 will convey size indexes 100 and 155 to allow canning of a blend pack of 120 or of canning the two discrete sizes.

TABLE 9

Selected Diameters of Asparagus Spears
for Machine-Sizing Operations
by Spear Size Index
California, 1964

Spear size index	Spear diameter
	inches
s ₂₇₁	6/16
s ₂₄₅	6/16
s ₁₅₅	6/16 to 8/16
s ₁₀₀	8/16 to 10/16
s ₇₇	10/16 to 14/16
s ₆₅	14/16 to 16/16

Work-sampling studies on the proportion of time spent in each element of the canning operation for all canner positions (Table 10) revealed an approximate 7.3 percent increase in actual canning time, as a percentage of total time, for white asparagus and a 10.2 percent increase for green asparagus over the conventional method when the commodity is presized prior to its delivery to the canners.^{1/}

Work-sampling studies of presized operations also disclosed that there is approximately 4.5 percent more select time and 3.0 percent less actual canning time near the lower end of the canning belt than was found in the upper end. This time differential was a significant change from the select can percentage changes calculated from observations of the conventional canning method.

There are several serious limitations to presenting a direct comparison between the conventional and presized methods of asparagus canning. Due to the fact that a single range or two distinctly separate size ranges transverse on a single canning belt, a separate variable for size has been omitted in the presized analysis. In addition, since line-load is such an important variable under the conventional canning method, and since there may be numerous line-loads present under the presized operation accompanied by pack-out fluctuations reflecting the distribution of asparagus sizes entering the plant, a separate line-load variable for each canning line has been omitted from this analysis. Line-load for a presized canning operation will mean line-load over all canners and all canning belts. This definition allows for a comparison of the same line-load under the two methods of sizing asparagus.

Within the bounds of the above restrictions, equations for determining the time to can a single No. 300 can-size equivalent of white asparagus for each canning line under the presized method are shown in Table 11. The particular sizes of

^{1/} See Tables 6 and 7, pp. 23 and 24, for a summary of the conventional canning method.

TABLE 10

Canners' Time by Work Element and Average of All Canner Positions
 as a Percentage of Total Time for Canning
 Presized Green and White Asparagus
 California, 1964

Work element	White asparagus ^{a/}	Green asparagus ^{b/c/}
	percent	
Secure empty	4.6	6.2
Select	54.8	57.4
Can	27.1	28.4
Set aside full	9.9	6.4
Miscellaneous	0.5	0.3
Wait	3.1	1.3
Total	100.0	100.0

a/ 925 individual observations.

b/ 1,837 individual observations.

c/ For comparison with manual sizing, see Table 6, p. 23.

asparagus shown in Table 11 represent a weighting of the total line-load as to the proportions previously discussed on page 32.

TABLE 11

Regression Equation for the Computation of Cans Per Minute for Canning Presized White Asparagus, by Paired Canner Positions and Canning Line for a Combined Line-Load of 170 Cans Per Canner Hour California, 1964

Canning belt number	Mean spear size index	Equation
1	77	$P_{77i} = 4.8630 - 0.3863(X_i), 1 \leq X_i \leq 5$
2	179	$P_{179j} = 3.6518 - 0.2040(X_j), 1 \leq X_j \leq 10$
3	120	$P_{120k} = 4.0691 - 0.2289(X_k), 1 \leq X_k \leq 9$

An important feature of the presized method is concerned with the "canner shuffle" where one or more of the canners must change cannning lines due to a lack of supply of a particular size blend. Large and frequent fluctuations in the size distribution of asparagus entering the plant could offset most of the advantages claimed for presizing. However, a part of this size or proportion change can be taken up by the canners on the cannning belt receiving the increase since increases in line-load have a positive effect on canner productivity. Data were unavailable in the amounts and detail required for analysis of this problem.

Comparison of Presized and Conventional Canning Methods

Using equation (8), the computational model equation, and the three equations shown in Table 11, it is possible to compare the presized and conventional methods of canning white asparagus spears discussed above.

Utilizing a line-load of 170 cans per canner hour, equation (8)--subject to the distribution and constraints shown in Table 5--yields 6,078 cans per line

hour.^{1/} To obtain this output, 38 cannery workers were employed. This same output can be obtained by using 32 cannery workers under the presized method of operation with a capacity to handle an additional 157 cans per hour.

With spear distributions as described on page 32, the presized asparagus lines would employ the following number of cannery workers: line number 1, 6 cannery workers; line number 2, 11 cannery workers; and line number 3, 15 cannery workers (Table 12).

The reciprocal forms of the three presized asparagus equations listed in Table 11 are shown in Figure 6 along with the corresponding times under the conventional method. Line number 1 reflects little difference between the two methods of sizing due to a relatively small volume of spears. Lines 2 and 3, however, reflect significant differences in time to can.

The difference in labor requirement between the conventional and presized canning methods will be proportionately constant since cannery output rates in equations (3) and (8) are linearly related to line-load. The six cannery worker differential at a line-load of 170 cans per worker hour results in a reduction of labor costs of \$13.46 per hour. For plants with an operating season of 500 hours, this differential would amount to \$6,730.

The above examples indicate, under the assumptions made, some of the short-term cost relations involved in utilizing a presized asparagus operation. Numerous other conditions can be analyzed using essentially the same calculating procedures as outlined above. A complete analysis would require consideration of the relative investment costs between the presized and conventional canning operations together with labor and other variable costs.

^{1/} The reader should remember to multiply each paired cannery worker position by two to determine total output.

TABLE 12

Estimated Time to Can Presized White Asparagus, by Canner Position and Canning Line, for a Combined Line-Load of 170 Cans Per Canner Hour
California, 1964

Paired canner position	Canning belt number		
	1	2	3
	Mean spear size index		
	77	179	120
minutes per can			
1	0.223	0.290	0.260
2	0.244	0.308	0.277
3	0.270	0.328	0.296
4	a/	0.353	0.317
5		0.380	0.342
6		0.412	0.371
7			0.405
8			0.447

a/ Blanks denote zero.

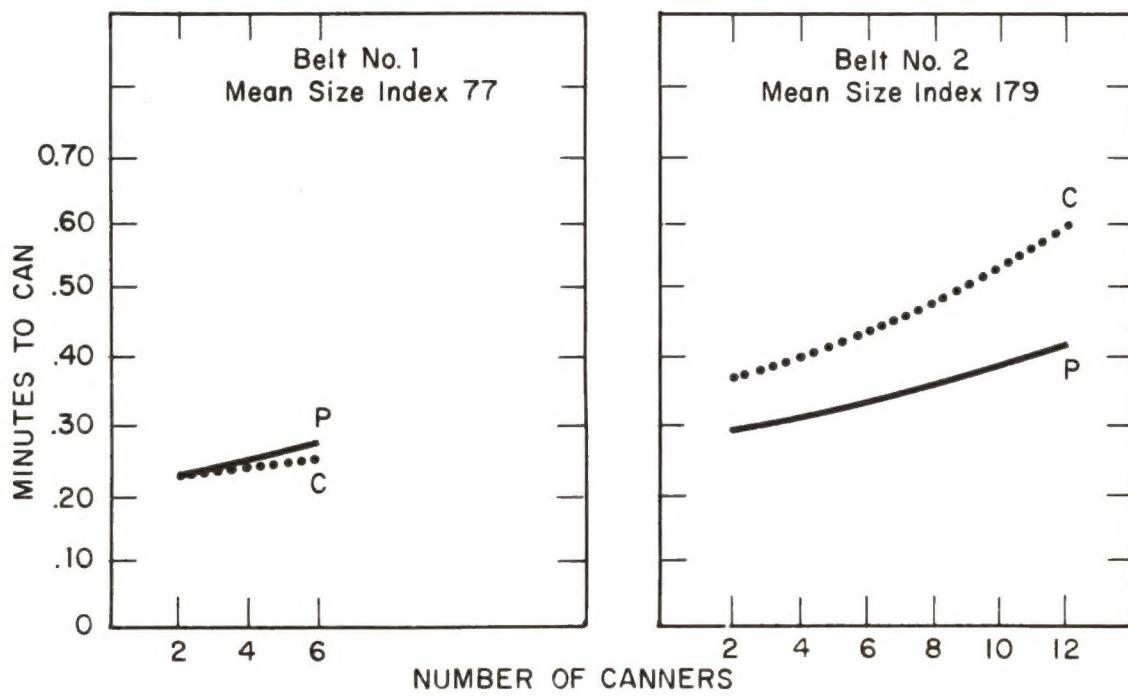
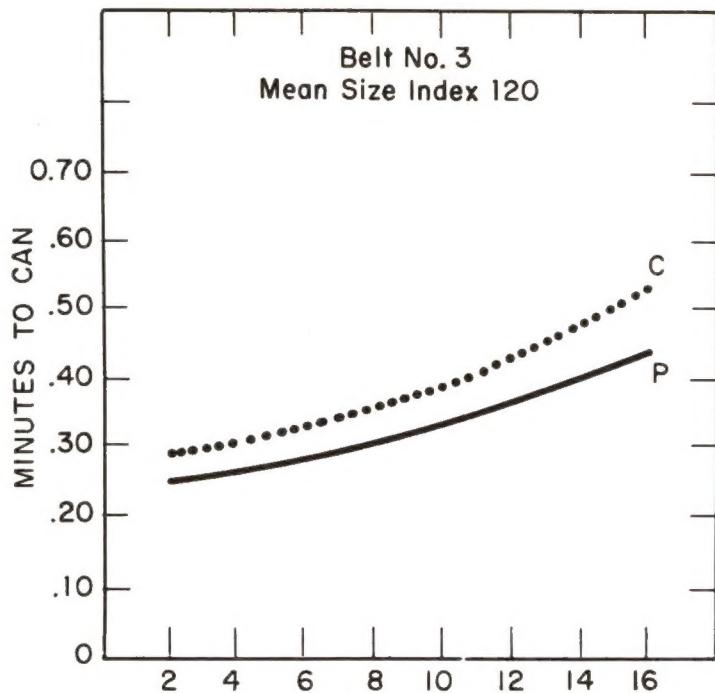


Figure 6. Relationships Between Time to Can For Presized and Conventional Canning Methods by Canning Belt, California, 1964.

APPENDIX TABLE 1

Summary of Computed Results for the 61 Variable
 White Asparagus Model
 California, 1964

Variable	Coefficient	Standard error	t ratio
a_0	0.86533		
L_{ijqm}	0.01789	0.00393	4.54299
S_{ijqm}	-0.00796	0.00206	3.85086
<u>Canner position</u>			
$b_{1,1}$	2.22535	0.79141	2.81184
$b_{1,2}$	<u>-a/</u>		
$b_{1,3}$	0.50794	0.47717	1.06447
$b_{1,4}$	0.42817	0.48569	0.88157
$b_{1,5}$	1.44669	0.44335	3.26305
$b_{1,6}$	0.07169	0.44335	0.16170
$b_{1,7}$	--		
$b_{1,8}$	-0.13500	0.36971	0.36516
$b_{1,9}$	-0.00324	0.34921	0.00928
$b_{1,10}$	1.78211	0.98677	1.80600
$b_{1,11}$	1.80346	0.78306	2.30307
$b_{1,12}$	2.07057	0.75707	2.73496
$b_{1,13}$	1.83890	0.73868	2.48943
$b_{1,14}$	0.84917	0.85208	0.99658
$b_{1,15}$	1.34302	0.60478	2.22066
$b_{1,16}$	1.20904	0.54561	2.21594
$b_{1,17}$	0.18681	0.72208	0.25870
$b_{1,18}$	-0.02829	0.33210	0.08521

(Continued on next page.)

APPENDIX TABLE 1--continued.

Variable	Coefficient	Standard error	t ratio
<u>Size</u>			
$b_{2,65}$	-1.14155	0.88639	1.28786
$b_{2,77}$	-0.11636	0.50924	0.22851
$b_{2,100}$	--		
$b_{2,155}$	2.27949	0.72306	3.15253
$b_{2,245}$	1.14951	0.52454	2.19144
<u>Position-size interaction term</u>			
$b_{3,1.1}$	--		
$b_{3,2.1}$	2.37597	0.83929	2.83091
$b_{3,3.1}$	1.10374	0.80777	1.36640
$b_{3,4.1}$	0.65902	1.03152	0.63888
$b_{3,4.2}$	-0.00147	0.68545	0.00215
$b_{3,5.2}$	-0.93558	0.65315	1.43240
$b_{3,6.2}$	0.30141	0.65315	0.46147
$b_{3,7.2}$	-0.07334	0.48198	0.15217
$b_{3,8.2}$	-0.15075	0.62180	0.24245
$b_{3,9.2}$	-0.64288	0.67065	0.95859
$b_{3,10.2}$	-2.17198	1.16706	1.86106
$b_{3,10.3}$	-2.06046	1.04399	1.97362
$b_{3,11.2}$	-2.67833	1.00236	2.67201
$b_{3,11.3}$	-2.18227	0.86621	2.51933
$b_{3,12.2}$	-3.07045	0.98274	3.12437
$b_{3,12.3}$	-3.00303	0.85843	3.49827
$b_{3,13.2}$	-2.42878	1.08123	2.24629

APPENDIX TABLE 1--continued.

Variable	Coefficient	Standard error	t ratio
$b_{3,13.3}$	-3.05174	0.86795	3.51603
$b_{3,14.3}$	-1.85205	0.96853	1.91223
$b_{3,14.4}$	0.95559	1.11673	0.85569
$b_{3,15.3}$	-3.09078	0.84222	3.66977
$b_{3,15.4}$	0.54329	0.94779	0.57322
$b_{3,16.3}$	-3.37680	0.80019	4.21998
$b_{3,16.4}$	0.08647	0.96978	0.08917
$b_{3,17.3}$	-2.45457	1.03959	2.36107
$b_{3,17.4}$	0.98311	1.20633	0.81496
$b_{3,17.5}$	0.97681	0.89782	1.08798
$b_{3,18.4}$	0.22322	0.90036	0.24793
$b_{3,18.5}$	1.18842	0.66868	1.77724
<u>Day</u>			
$b_{4,1}$	0.24204	0.23774	1.01808
$b_{4,2}$	-0.03134	0.15141	0.20703
$b_{4,3}$	--		
$b_{4,4}$	0.06250	0.16688	0.37454
$b_{4,5}$	-0.01211	0.14946	0.08106
$b_{4,6}$	0.02712	0.23916	0.11342

a/ Dashes indicate coefficient dropped due to insignificance.